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Best Management Practices to Minimize Nonpoint-Source Pollution in Agriculture

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Growing concern about the environmental impacts of intensive agricultural production on natural resources, including soil, water, and air, has led to development of *best management practices* (BMPs), which are effective, practical, and structural or nonstructural methods adopted to optimize crop production and minimize environmental impacts. In general, agricultural BMPs prevent or reduce the movement of sediment, nutrients, pesticides, and other pollutants from the land to surface water bodies or groundwater. The goal of developing BMPs is to achieve a balance between crop production and environmental protection.

Successful crop production requires an understanding of the basics of agriculture including management principles for soils, water, nutrients, crop residues, pests, and tillage systems (conventional, minimum, no-till, ridge tillage, etc.).

This publication is based on principles we recently described in journal articles on BMPs for citrus cultivation (Abbas and Fares 2009a, Fares 2009), and it briefly outlines BMPs for the following areas:

- field crop production
- soil management
- water management
- irrigation management
- nutrient management and planning
- integrated pest management
- pesticide storage, handling, and application
- fish and wildlife habitat, farm forestry, or woodland management
- home, lawn, and garden
- air quality and particulate matter (PM₁₀) reduction

Field crop production

Profitable crop production aims at producing high yields with minimum inputs. For enhanced crop production and efficient resource use, a cropping system can be a mixture of cash crops and nitrogen-fixing legumes—the companion cover crops. In such integrated cropping systems, cash and cover crops are rotated so that the following crops take up nutrients left by the previous crops, and both contribute to plant residue-based soil nutrients. In these systems, the crops cover the soil surface and protect it from erosive forces of winds and rainfall. In orchards, the cover crops control soil erosion by protecting the areas between tree rows and stabilizing the soil with their roots.

Soil management

“Soil management” refers to techniques to maintain good soil structure (tilth) and conditions that contribute to high yields and good returns on inputs while having minimal adverse environmental impacts. Good soil management averts problems such as soil erosion, surface water runoff, soil compaction, and loss of soil or surface organic matter. Soil management techniques vary from conventional tillage to minimum-tillage to no-tillage systems, and they include adding organic matter through incorporation of crop residues, green manure or cover crops, or other sources, such as composted animal manures, imported to the field. Conventional tillage turns over the soil for weed control, conditions it for seedbed preparation, and incorporates amendments. Minimum tillage does not turn the soil over in the beginning of a growing season for seedbed preparation but allows physical disturbance of the soil surface for manure incorporation and weed

eradication through shallow disking or hand-hoeing. No-tillage restricts any form of physical soil disturbance at any stage of cropping season.

Soil management requires soil structure stabilization. Application of livestock manures stabilizes soil structure by improving physical properties (soil bulk density and total porosity) and hydrological properties (infiltration rates and saturated hydraulic conductivity) (Fares et al. 2008). Stabilized soil structure enhances crop production and ensures reduced soil erosion.

During soil management, “cross-wind ridges” should be used: soil ridges formed by a tillage operation should be oriented across the usual wind direction to serve as a windbreak (Thelander et al. 2008). The following points should be kept in mind while developing cross-wind ridges:

- Wind direction is a major factor to consider when constructing ridges by tillage and/or by planting row crops.
- Ridges exactly (or nearly) perpendicular to the prevailing wind direction yield maximum benefits.
- Deteriorated (and hence ineffective) ridges must be re-established to avoid possible damage to the standing crops.
- Stable soils (i.e., clays, silts, and sandy loams) will effectively sustain ridges; unstable soils (i.e., sands, loamy sands, and certain organic soils) are not suitable for constructing ridges.
- Cross-wind strip cropping or cross-wind vegetative strips should also be considered.

Water management

“Water management” refers to practices for planning, developing, distributing, and optimally utilizing water resources under defined water policies and regulations. Market forces play a vital role in better water management (Lankford and Gowing 1997). Water management also includes treatment of drinking, industrial, sewage, or wastewater for reuse; management of water resources (i.e., lakes, rivers, canals, streams, and water channels); and management and protection of water supplies including reservoirs, tanks, pipes, and on-farm irrigation systems.

Water is precious and a basic component of agriculture. Protecting water supplies guarantees profitable farm operations, the farm family’s health, and the well being of downstream users. In general, water users should

- Get to know the water requirements of crops and home lawns so that fresh water use for irrigation is minimized.

- Preferably, use recycled and treated wastewater to irrigate crops and home lawns.

Irrigation management

Irrigation water requirements for various crops vary with their growth stages. “Irrigation management” means right-time application of the right amount of irrigation water to the crops. In general, irrigation management involves overall soil moisture management throughout the growing season for high quality crop production. Irrigation scheduling can be based on water budget calculation, observation of plant water stress, or measurement of soil water status or pan evaporation to answer two essential questions: when to irrigate and how much to irrigate (Fares 2009). The goals are (1) to start irrigation when the depletion level of the available soil water has been reached, and (2) to stop the irrigation when the average water content in the rootzone reaches field capacity. Efficient irrigation management makes sure that the crop water requirements are fulfilled for enhanced crop production with the least environmental impact. Irrigation management requires selection and design of irrigation application systems followed by determination and implementation of irrigation scheduling.

Microsprinklers, drip or trickle lines, and surface/flood irrigation are among the common irrigation systems (Kusakabe et al. 2006). Feasibility of these systems is based on the scale of farming, topography, soil texture, irrigation water availability, and affordability. One system may be more efficient under one set of conditions but may not be better than the others under different sets of conditions, due to the irrigation system’s water use efficiency, which varies with soil properties and crop characteristics and not with the application system itself (Tennakoon and Milroy 2003). Soil properties, such as soil texture, structure, organic matter content, permeability, water holding capacity, and infiltration rate, influence irrigation water use efficiency (Viets 1962). Crop characteristics that influence irrigation water use efficiency include plant root structure, root distribution, and rooting depth or stage (Tennakoon and Milroy 2003). Irrigation water use efficiency generally refers to (1) the volume of water beneficially used relative to the volume delivered from an irrigation system, or (2) the increase in crop yield over non-irrigated yield relative to the volume of water applied by an irrigation system (Smajstrla et al. 1991). Pressurized irrigation systems (i.e., sprinkler and drip systems) have substantially higher

irrigation efficiency compared to traditional surface irrigation methods (Sanchez and Peralta 2003). Optimal irrigation scheduling for any irrigation system is based on information regarding available soil water content, crop evapotranspiration, rainfall, and crop parameters.

Nutrient management and planning

“Nutrient management and planning” means the application of precise amounts of nutrients to the soil according to the crop nutrient requirements to prevent the contamination of surface and ground water bodies. To adopt this practice, we should

- Understand the principles of nutrient management.
- Know the soil and landscape features.
- Know the soil fertility reserves.
- Know the crop’s nutrient requirements.
- Calibrate application equipment to know how much we are applying.
- Implement best management practices for application of nutrients (i.e., precautionary measures).
- Adopt best management practices for soil and water conservation to avoid nutrient leaching.

Nutrient management and planning also involves selecting and using various organic source of nutrients, e.g., organic manure amendments, the wise use of which is considered environmentally friendly. Application of organic manure amendments to the soil not only fulfills crop nutrient requirements but also sequesters carbon in soil (Abbas and Fares 2009b). The following should be considered when using livestock manure as a nutrient source:

- Local, state, and federal laws and regulations must be followed during manure application.
- Take all precautionary measure to control any accidental leakage, spillage, or runoff of pollutants from manure stored at and/or applied to a field that is near a water body or source.
- Certain manures, e.g., chicken manure, can be volatile and contribute a noxious odor to the environment through ammonia emission; make efforts to reduce such emissions during manure storage and application.

Integrated pest management

Integrated pest management (IPM) involves pest monitoring, pest identification, and pest control. IPM is a holistic approach for prevention of pest problems and reduction in use of pesticides that may adversely affect

the environment or the materials being protected. Successful IPM for any insects or pests requires determining whether the presence of the pests or their population density within the crop is high enough to cause economic loss (Dufour 2001). IMP also uses a combination of techniques including organic, conventional, and biological farming practices. The options include:

- pest-resistant cultivar selection
- vintegrated crop rotation
- maintaining better sanitation conditions
- biological control with mulching
- removal or eradication of the affected plants
- selection of planting and harvesting dates
- pesticide timing and application.

Integrated pest management is an increasingly popular way to control crop diseases and insect pests. By applying a mix of cultural, biological, and chemical control methods, growers can save money on inputs and use fewer pesticide applications.

Pesticide storage, handling, and application

Pesticides are an important input for many cropping systems. If mishandled or misused, they can be toxic to the pesticide handler and can put water supplies, and the people and animals that come in contact with them, at risk. Because a safe and effective ecosystem is important for environment protection and our safety, we should practice the following BMPs:

- Buy pesticides in small quantities.
- Store them in a secured area.
- Dispose of them in accordance with federal, state, and local regulations.
- Maintain application equipment in working condition, and calibrate the equipment frequently to ensure recommended rates are applied.
- Ensure that the pesticide applicator knows the exact location of the field to be treated.
- Post warning signs around fields that have been treated according to the local, state, and federal laws.
- Make sure to post and observe the re-entry time stated on the label.
- Avoid unnecessary application of pesticides.
- Avoid overspray and drift, especially when surface water is in close proximity to treated fields.
- Avoid pesticide application when soil moisture status is high, to prevent possible runoff or deep percolation.
- Avoid irrigation right after a pesticide application.

- Establish buffer zones to maintain a safe distance from wells and surface water (minimum 50–100 feet recommended); do not apply pesticides in buffer zones.
- Avoid repetitive use of the same pesticide, which may lead to development of pesticide resistance in the pest.
- Read and follow safety directions, and maintain appropriate Material Safety Data Sheets.
- Use appropriate protective equipment specified on the pesticide label to minimize unnecessary exposure.
- Formulate a safety plan and provide emergency hand and eye wash facilities for personnel who might be accidentally exposed to pesticides.
- Have a pesticide first aid kit available when handling pesticides.

Fish and wildlife habitat, farm forestry, and woodland management

“Fish and wildlife habitat management” means managing the areas specific to fish and wildlife to provide them habitats in an ecosystem.

Many long-term environmental and economic benefits can accrue from thoughtfully managing wildlife habitats, including forested areas, on your property. Restored or improved habitats are compatible with farming, good for soil and water, often profitable, and usually practical. The habitat management practice includes ways to help prevent wildlife from becoming a problem and provides advice on what to do when wildlife become a nuisance.

“Farm forestry and habitat management” means

- planting windbreaks, shelterbelts, and natural fencerows
- clearing and reforesting marginal and fragile lands
- planting buffer strips around water bodies
- intercropping field crops and trees
- planting trees and allowing livestock access
- managing woodlands for profit and the environment
- producing quality timber, firewood, posts, and poles.

Benefits of managed woodlands include reliable returns, products for on-farm use, and resource and habitat protection.

Home, lawn, and garden BMPs

Disposal of household waste contributes to serious water pollution problem. The following home BMPs need to be practiced to avoid water pollution problems (Idaho 2005):

- Use sink or other regular/working outlets to dispose of water from carpet cleaning, upholstery, and other surfaces.
- Pressure-washing home driveways and/or roofs may

generate wastewater that contains pollutants. Such wastewater should be directly discharged through a drainage system.

- To avoid water pollution problems, do not overwater, over-fertilize, improperly apply herbicide, or dispose of clippings.
- When applying fertilizers or pesticides to lawns or home gardens, use the recommended dosages and application practices specified on the product label.

Air quality and particulate matter (PM₁₀) reduction

The federal Air Quality Act requires that emissions from all significant sources must be controlled to meet the national ambient air quality standards. The act requires growers to implement and maintain at least a few of the approved BMPs for each of the following three categories (Thelander et al. 2008).

Category I: Tillage and harvest

This includes any mechanical practice that physically disturbs cropland; BMPs for use during tillage and harvest are

- cessation of night tillage
- limited activity during high wind events
- chemical irrigation
- multi-year crops
- combining tractor operations
- planting based on soil moisture
- equipment modification
- precision farming
- green chop
- reduced harvest activity
- integrated pest management
- reduced tillage system
- tillage based on soil moisture
- timing of tillage operations.

Category II: Non-cropland

BMPs for use on non-cropland include

- access restriction
- reduced vehicle speed
- aggregate cover
- synthetic particulate suppressant
- artificial wind barrier
- track-out control system
- critical-area planting
- tree, shrub, or windbreak planting

- manure applications
- watering.

Category III: Cropland

BMPs for use on cropland include

- artificial wind barriers
- mulching
- cover crops
- multi-year crops
- cross-wind ridges
- permanent cover
- cross-wind strip-cropping
- planting based on moisture
- cross-wind vegetative cropping
- residue management
- cross-wind vegetative strips
- sequential cropping
- integrated pest management
- surface roughening
- manure applications
- tree, shrub, or windbreak planting.

Summary

Agricultural best management practices are designed to prevent and/or reduce the movement of sediment, nutrients, pesticides, and other pollutants from the land to surface waters, groundwater, coastal areas, and the ocean. Developing holistic management practices and implementing sustainable BMPs in agricultural areas require the concerted intentions of concerned growers, with support from government agencies and regulatory bodies. Information provided in this publication gives an overview of most of these relevant BMPs and should help growers in their mission to adapt these practices to Hawai'i's various crop production situations.

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Additional resources

For further Hawai'i-specific information on best manage-

ment recommendations, visit <http://www.ctahr.hawaii.edu/freepubs> and choose the category Soil and Crop Management. For further advice on farm-based strategies to minimize pollution that may result from agricultural activities, choose the category Hawaii's Pollution Prevention Information. For more about safe handling and use of agricultural pesticides, see the category Pesticide Risk Reduction Education.